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(54) **OPTICAL BOARD, METHOD FOR MANUFACTURING THE SAME, AND OPTICAL MODULE STRUCTURE**

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(30) **Foreign Application Priority Data**

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Oct. 18, 2012 (JP) 2012-230615

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G02B 6/12 (2006.01)
G02B 6/42 (2006.01)

(52) **U.S. Cl.**
CPC ***G02B 6/12*** (2013.01); ***G02B 6/4214*** (2013.01); ***G02B 6/4274*** (2013.01)

(58) **Field of Classification Search**
CPC G02B 6/12; G02B 6/26; G02B 6/4214; G02B 6/43; G02B 6/42; G02B 6/428; G02B 6/13
USPC 385/14, 31, 65, 83
See application file for complete search history.

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(57) **ABSTRACT**

An optical board including a substrate including a plate-shaped resin including a first main plane and a second main plane facing each other, and a slit-shaped optical fiber receiving portion which penetrates between the first main plane and the second main plane in a thickness direction, a metal layer provided on the second main plane, and a wiring pattern consisting of metal and provided on the first main plane. An inclined plane is provided at an end of the optical fiber receiving portion in the substrate, a tilt angle of the inclined plane with respect to the first main plane is an obtuse angle, and a reflective layer is provided on the inclined plane for reflecting a light output from an optical fiber received in the optical fiber receiving portion toward the first main plane.

19 Claims, 7 Drawing Sheets

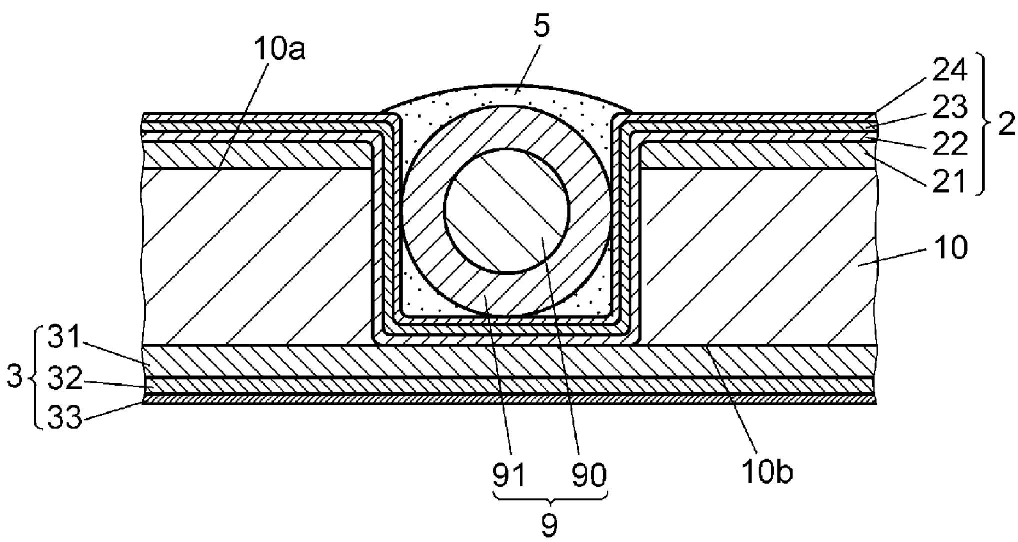
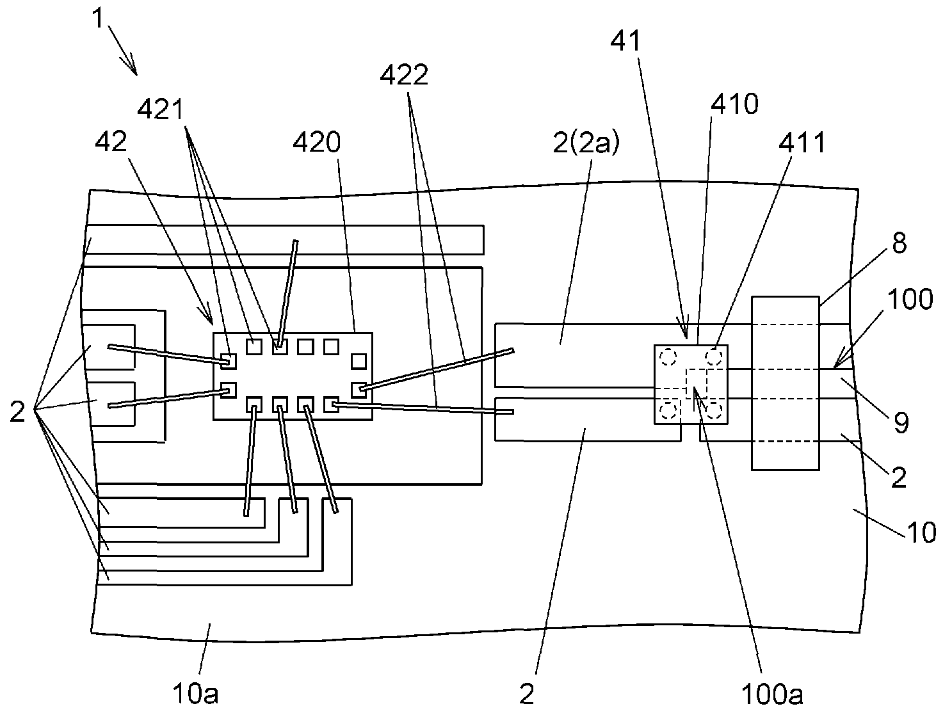


FIG.1A


1
421
42
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8
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100a

FIG.1B

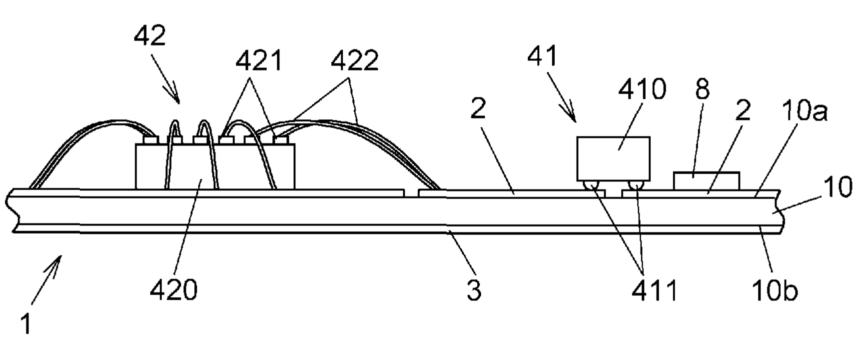
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FIG.2A

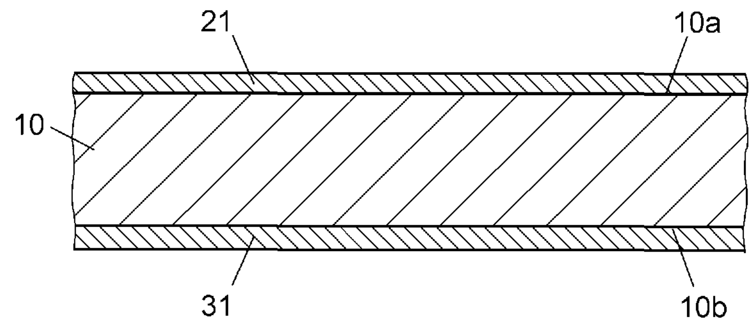


FIG.2B

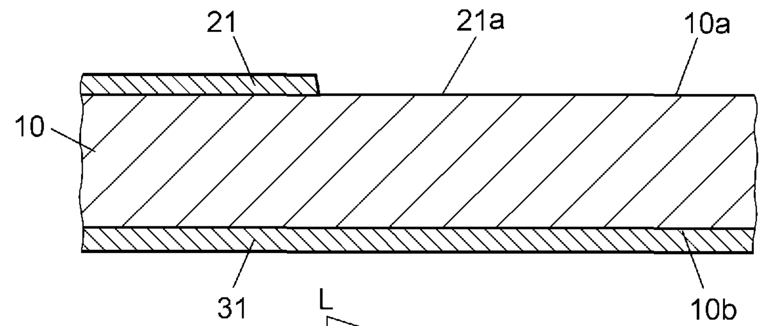


FIG.2C

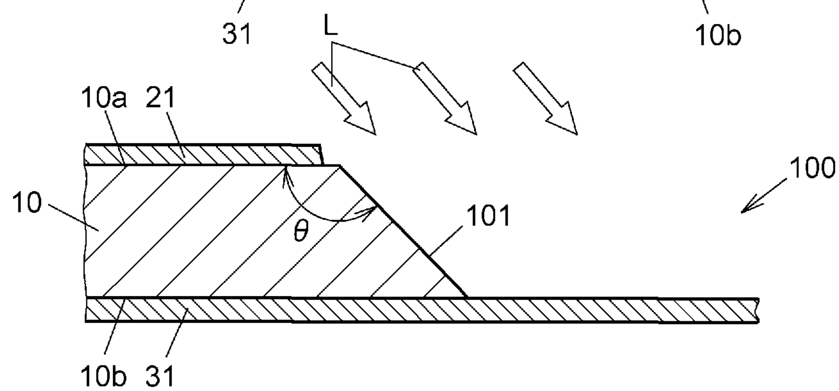


FIG.2D

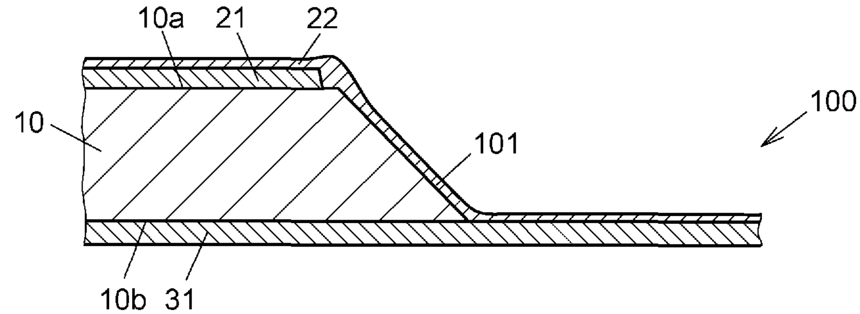


FIG.2E

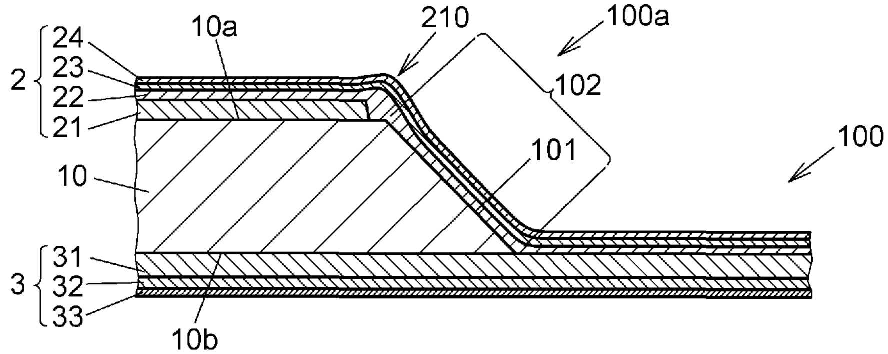


FIG.3A

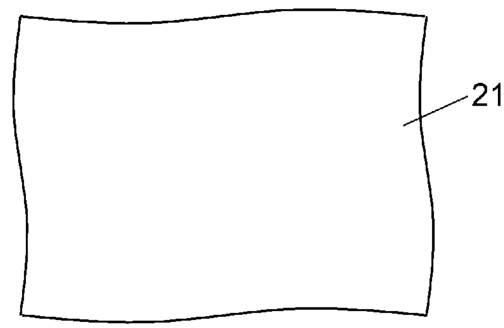


FIG.3B

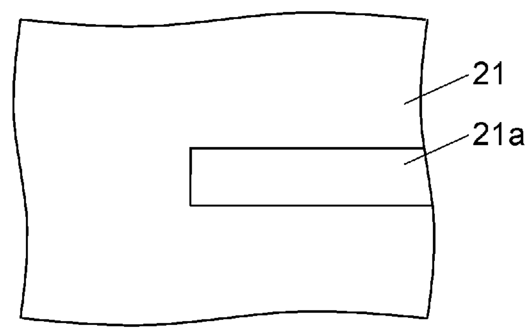


FIG.3C

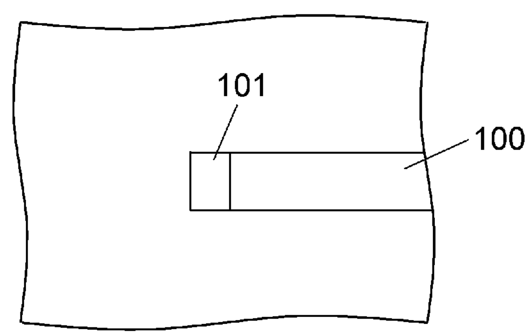


FIG.3D

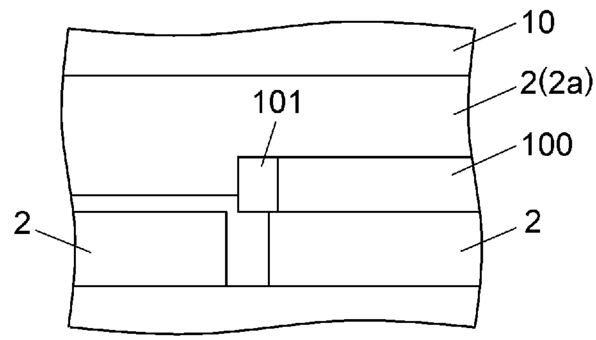
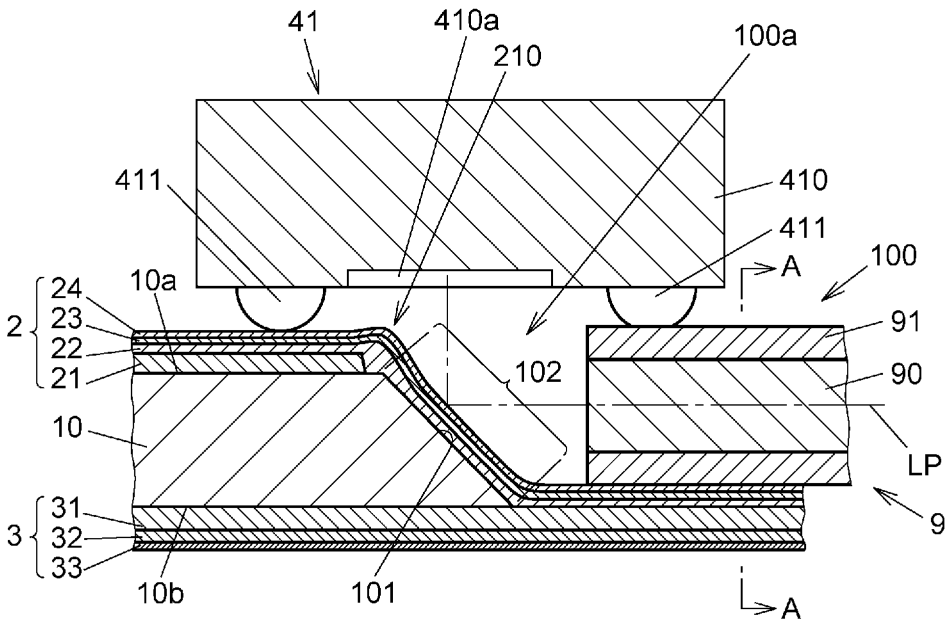


FIG.4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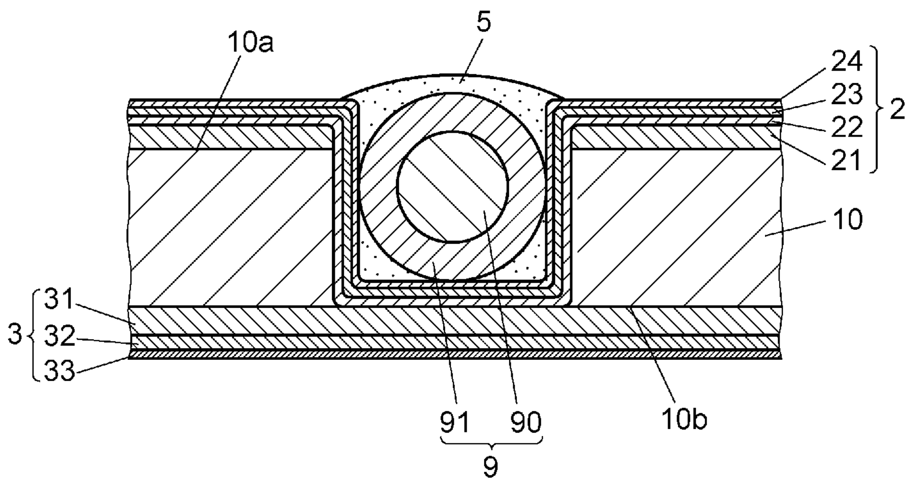
410a
210
100a
411
410
411
100
A
24
23
22
21
2
10a
91
90
102
LP
10
9
31
32
33
3
10b
101
A

FIG.5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10a
24
23
22
21
2
10
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32
33
3
91
90
9
10b

FIG.6A

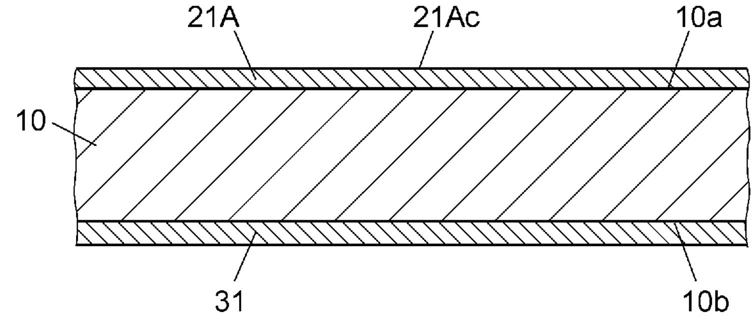


FIG.6B

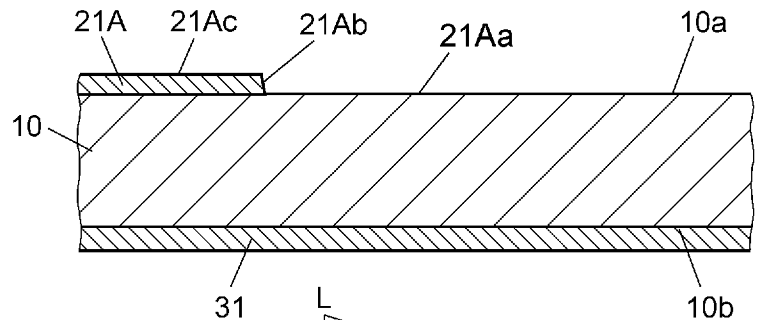


FIG.6C

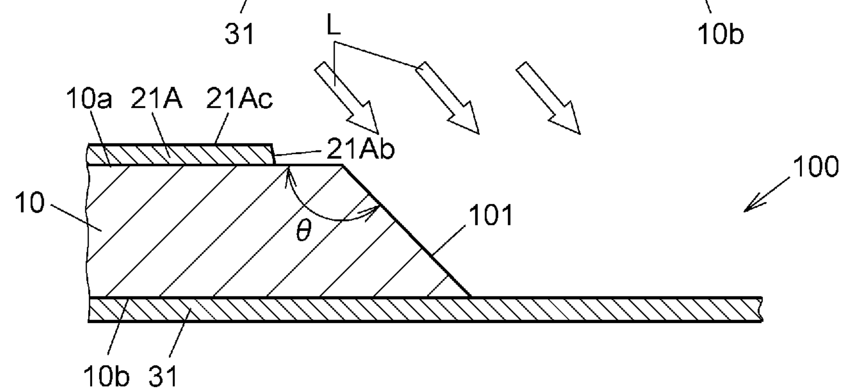


FIG.6D

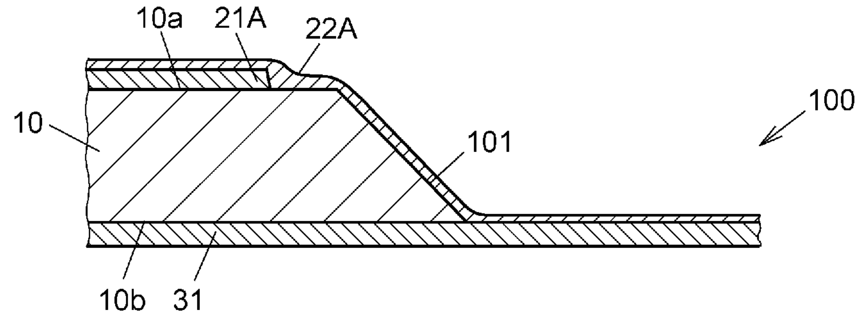


FIG.6E

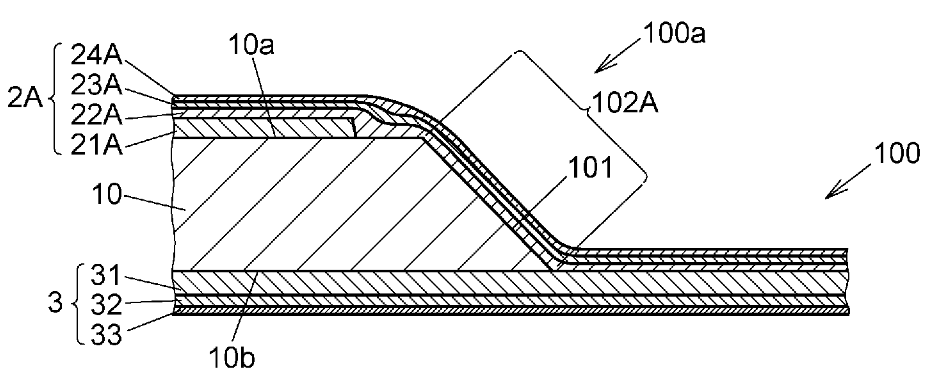


FIG.7A

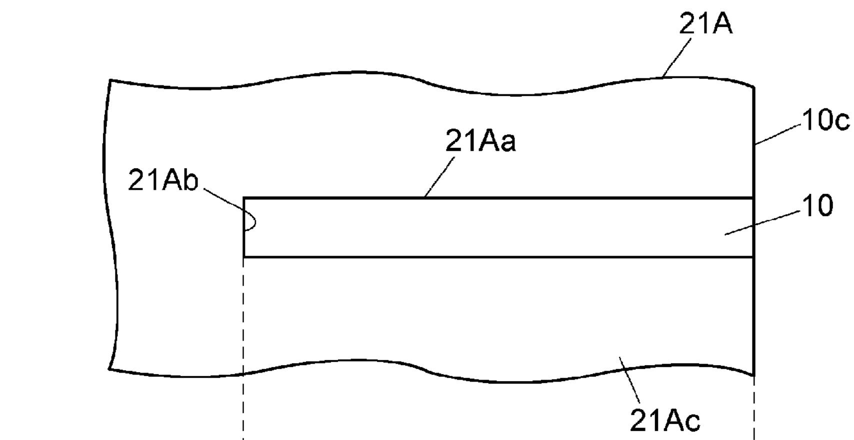


FIG.7B

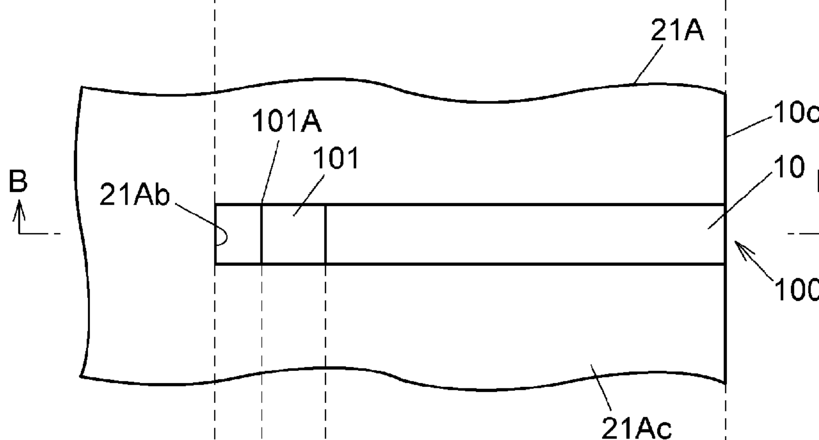


FIG.7C

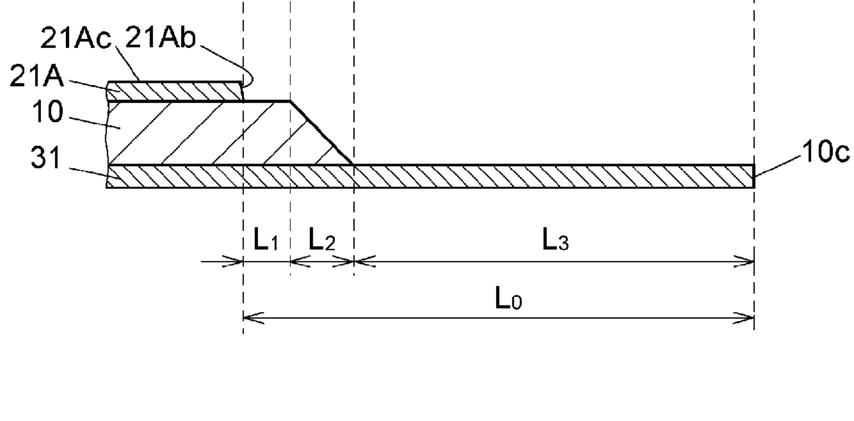
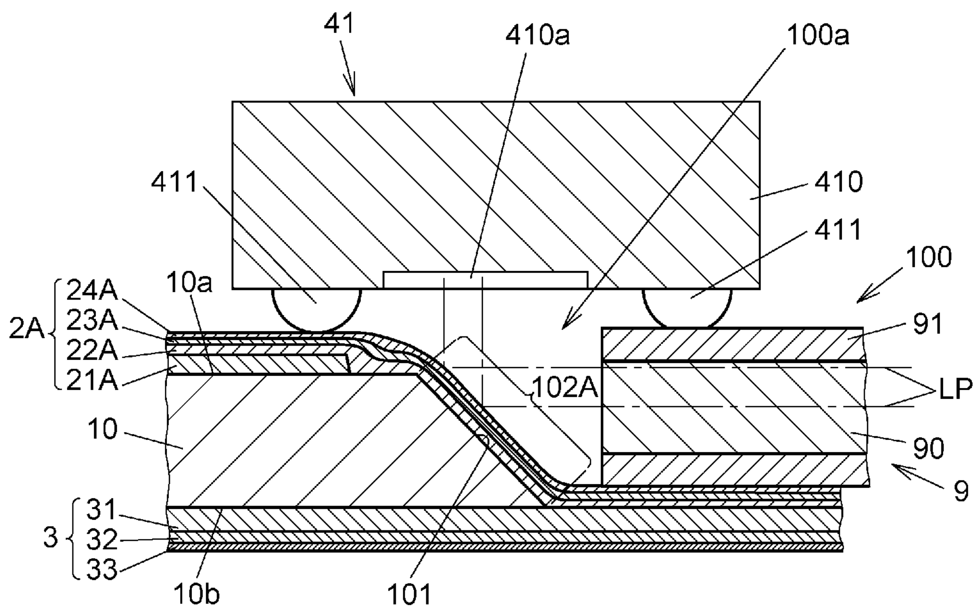


FIG.8


41
410a
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410
411
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24A
10a
2A
23A
22A
21A
91
102A
LP
10
90
9
31
3
32
33
10b
101

OPTICAL BOARD, METHOD FOR MANUFACTURING THE SAME, AND OPTICAL MODULE STRUCTURE

The present application is based on Japanese patent application No. 2011-288307 filed on Dec. 28, 2011 and Japanese patent application No. 2012-230615 filed on Oct. 18, 2012, the entire contents of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an optical board, a method for manufacturing an optical board, and an optical module structure, more particularly, to an optical board for receiving an optical fiber, a method for manufacturing the same, and an optical module structure with an optical board.

2. Description of the Related Art

Conventionally, an optical mounting board which has a groove for holding an optical fiber and on which a photoelectric conversion device is mounted has been known as disclosed by Japanese Laid-Open Publication No. 2003-167175 (JP-A 2003-167175).

The optical mounting board disclosed by JP-A 2003-167175 is formed by pressing a die having a triangular pole-shaped protrusion (a protrusion having a triangular cross section) on a substrate material which is softened. On the optical mounting board, a guide groove with a shape corresponding to the protrusion of the die is formed and a tapered plane is formed at an end of this guide groove. A reflecting plane is formed by plating a metal layer or pasting a mirror on the tapered plane to reflect an output light of the optical fiber held in the guide groove toward a light receiving element.

SUMMARY OF THE INVENTION

However, the optical mounting board disclosed by JP-A 2003-167175 requires an expensive manufacturing equipment, since the die is used for the formation of the guide groove and the tapered plane.

Accordingly, it is an object of the present invention to provide an optical board, a method for manufacturing an optical board, and an optical module structure, by which the manufacturing cost can be reduced.

According to a first feature of the invention, an optical board comprises:

a substrate including a plate-shaped resin including a first main plane and a second main plane facing each other, and a slit-shaped optical fiber receiving portion which penetrates between the first main plane and the second main plane in a thickness direction;

a metal layer provided on the second main plane; and

a wiring pattern consisting of metal and provided on the first main plane,

wherein an inclined plane is provided at an end of the optical fiber receiving portion in the substrate, a tilt angle of the inclined plane with respect to the first main plane is an obtuse angle, and a reflective layer is provided on the inclined plane for reflecting a light output from an optical fiber received in the optical fiber receiving portion toward the first main plane.

According to a second feature of the invention, a method for manufacturing an optical board comprises:

a first step of forming a first metal layer on a first main plane of a substrate comprising a plate-shaped resin as well as forming a metal layer on a second main plane;

a second step of partially removing the first metal layer to expose a strip-shaped portion; and

a third step of irradiating laser beam obliquely to the exposed strip-shaped portion, to form an optical fiber receiving portion and an inclined plane at an end of the optical fiber receiving portion.

According to a third feature of the invention, an optical module structure comprises:

an optical board comprising:

a substrate including a plate-shaped resin including a first main plane and a second main plane facing each other, and a slit-shaped optical fiber receiving portion which penetrates between the first main plane and the second main plane in a thickness direction;

a metal layer provided on the second main plane; and

a wiring pattern consisting of metal and provided on the first main plane; and

and a photoelectric conversion device for converting an optical signal to be transmitted through an optical fiber into an electric signal or an electric signal into the optical signal,

wherein an inclined plane is provided at an end of the optical fiber receiving portion in the substrate, a tilt angle of the inclined plane with respect to the first main plane is an obtuse angle, and a reflective layer is provided on the inclined plane for reflecting a light output from an optical fiber received in the optical fiber receiving portion toward the first main plane,

wherein the photoelectric conversion device is mounted on the first main plane, to cover the inclined plane.

EFFECTS OF THE INVENTION

According to an optical board, a method for manufacturing an optical board, and an optical module structure of the present invention, it is possible to reduce the manufacturing cost.

BRIEF DESCRIPTION OF THE DRAWINGS

Next, embodiments of the present invention will be described in conjunction with appended drawings, wherein:

FIGS. **1**A and **1**B show an example of a configuration of an optical board and an optical module structure with the optical board in the first embodiment according to the present invention, wherein FIG. **1**A is a plan view thereof, and FIG. **1**B is a side view thereof,

FIGS. **2**A to **2**E are cross-sectional views showing a process for forming a reflecting portion and a peripheral portion thereof in the optical board;

FIGS. **3**A to **3**D are plan views showing the process for forming the reflecting portion and the peripheral portion thereof the optical board as viewed from a side of a first main plane;

FIG. **4** is a cross-sectional view showing an example of the optical module structure in the first embodiment according to the present invention;

FIG. **5** is a cross-sectional view taken along line A-A of FIG. **4** showing an example of an optical module structure in a modification of the first embodiment;

FIGS. **6**A to **6**E are cross-sectional views showing the process for forming a reflecting portion and a peripheral portion thereof an optical board in the second embodiment as viewed from a side of a first main plane;

FIGS. **7**A and **7**B are plan views showing the process for forming the reflecting portion and the peripheral portion thereof the optical board in the second embodiment as viewed from the side of the first main plane;

FIG. **7**C is a cross-sectional view taken along line B-B of FIG. **7**B; and

FIG. **8** is a cross-sectional view showing an example of an optical module structure in the second embodiment.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Next, the embodiments of the present invention will be described in more detail in conjunction with the appended drawings.

First Embodiment

FIGS. **1**A and **1**B show an example of a configuration of an optical board and an optical module structure with the optical board in the first embodiment according to the present invention, wherein FIG. **1**A is a plan view thereof, and FIG. **1**B is a side view thereof.

An optical board **1** includes a plate-shaped substrate **10** having a first main plane **10***a* and a second main plane **10***b* that are facing each other. The substrate **10** is made of an insulating resin such as polyimide. The first main plane **10***a* and the second main plane **10***b* are parallel to each other, and the substrate **10** has a thickness of e.g. 70 μm. FIG. **1**A shows a state of the optical board **1** viewed from the side of the first main plane **10***a*.

The optical board **1** further includes a plurality of wiring patterns **2** made of an electrically conductive metal foil formed on the first main plane **10***a* of a substrate **10**, and an electrically conductive metal layer **3** formed on the second main plane **10***b*. In the present embodiment, the metal layer **3** is provided entirely over the second main plane **10***b*. A surface of a resin of the substrate **10** is exposed between respective wiring patterns of the plurality of wiring patterns **2**. The wiring patterns **2** located on a back side with respect to a photoelectric conversion device **41** and a retainer member **8** to be explained later are illustrated by broken lines in FIG. **1**

Further, the substrate **10** is provided with a slit-shaped optical fiber receiving portion **100**, which penetrates in the thickness direction of the substrate **10** and between the first main plane **10***a* and the second main plane **10***b* and which extends parallel to the first main plane **10***a* and the second main plane **10***b*. At one end (terminal) portion of the optical fiber receiving portion **100**, a light reflecting portion **100***a* for reflecting a light transmitted through an optical fiber **9** as a transmission medium is formed. The other end portion of the optical fiber receiving portion **100** is opened toward an end face (a side surface at the end portion of the substrate **10** between the first main plane **10***a* and the second main plane **10***b*) of the substrate **10**. The detailed configuration of the reflecting portion **100***a* will be described later.

The optical fiber **9** is accommodated (received) in the optical fiber receiving portion **100**. The optical fiber **9** is retained by the plate-shaped retainer member **8** attached to the first main plane **10***a* such that the optical fiber **9** will not move out from or slip off the optical fiber receiving portion **100**.

In the optical board **1**, the photoelectric conversion device **41** and a semiconductor circuit device **42** which is electrically connected to the photoelectric conversion device **41** are mounted on the wiring patterns **2** on the first main plane **10***a*. The photoelectric conversion device **41** is a device which converts an electrical signal into an optical signal or converts an optical signal into an electrical signal. As an example of the former one, a light emitting element such as semiconductor laser device, LED (Light Emitting Diode) may be cited. As an example of the latter one, a light receiving element such as photodiode may be cited. The photoelectric conversion device **41** is configured to output or input a light from a light emitting/receiving portion **410***a* formed on the side of the substrate **10** (see FIG. **4**) along a direction perpendicular to the substrate **10**.

When the photoelectric conversion device **41** is a device which converts an electrical signal into an optical signal, the semiconductor circuit device **42** is a driver IC for driving the photoelectric conversion device **41**. Alternatively, when the photoelectric conversion device **41** is a device which converts an optical signal into an electrical signal, the semiconductor circuit device **42** is a receiver IC which amplifies a received signal to be input from the photoelectric conversion device **41**.

In the present embodiment, the photoelectric conversion device **41** is flip-chip mounted on the substrate **10**, and a main body **410** is provided with four terminals (bumps) **411**. The four terminals **411** are connected to the wiring patterns **2**, respectively. In addition, the photoelectric conversion device **41** is mounted at such a position that the main body **410** faces the reflecting portion **100***a*.

If the photoelectric conversion device **41** is a device which converts an electrical signal into an optical signal, the reflecting portion **100***a* reflects the light output from the photoelectric conversion device **41** toward the end face of the optical fiber **9**. Alternatively, if the photoelectric conversion device **41** is a device which converts an optical signal into an electrical signal, the reflecting portion **100***a* reflects the light output from the optical fiber **9** toward the photoelectric conversion device **41**.

In the semiconductor circuit device **42**, a plurality of (the number is twelve in the example shown in FIG. **1**) terminals (electrode pads) **421** are provided on an opposite side of a surface facing the wiring patterns **2** in the main body **420**, and each terminal **421** is electrically connected to the wiring pattern **2** by a bonding wire **422**. Some of the terminals **421** are connected to the wiring patterns **2** to which terminals **411** of the photoelectric conversion device **41** are connected, so that the semiconductor circuit device **42** and the photoelectric conversion device **41** are electrically connected to each other.

Although not shown in FIG. **1**, connectors, IC (Integrated Circuit), and electronic parts such as active element (such as transistors) and passive element (such as resistor, capacitor) may be mounted on the optical board **1** in addition to the photoelectric conversion device **41** and the semiconductor circuit device **42**.

Next, a method of manufacturing the optical board **1** will be explained below with reference to FIGS. **2**A to **2**E and FIGS. **3**A to **3**D.

FIGS. **2**A to **2**E are cross-sectional views showing a process for forming a reflecting portion **100***a* and a peripheral portion thereof in the optical board **1**. FIGS. **3**A to **3**D are plan views showing the process for forming the reflecting portion **100***a* and the peripheral portion thereof the optical board **1** as viewed from a side of a first main plane **10***a*.

The manufacturing process of the optical board **1** has at least a first step of forming a first metal layer **21** on a first main plane **10***a* of a substrate **10** as well as forming a metal layer **31** on a second main plane **10***b* of the substrate **10**, a second step of partially removing the first metal layer **21** to expose a strip-shaped portion **21***a*, a third step of irradiating laser beam L obliquely to the exposed strip-shaped portion **21***a* of the first main plane **10***a*, to form the optical fiber receiving portion **100** and an inclined plane **101** at an end of the optical fiber receiving portion **100**, a fourth step of forming a second metal layer **22** on the inclined plane **101** and the first metal layer **21** of the first main plane **10***a*, and a fifth step of partially etching the first metal layer **21** and the second metal layer **22** to form a plurality of wiring patterns **2** on the first main plane **10***a*.

In the present embodiment, the manufacturing process further has a sixth step of plating gold (Au) and nickel (Ni) on the first and second metal layers **21**, **22** and the metal layer **31** on the side of the second main plane **10***b*. Next, the first to sixth steps will be described in more detail.

In the first step, as shown in FIGS. **2**A and **3**A, the first metal layer **21** is formed entirely on the first main plane **10***a* of the substrate **10** and the metal layer **31** is formed entirely on the second main plane **10***b*, respectively, by e.g. adhesion, vapor deposition, or electrolytic plating. In the present embodiment, the first metal layer **21** and the metal layer **31** are essentially consisting of copper (Cu) which is a good conductor. In the present embodiment, the metal layer **31** is formed thicker than the first metal layer **21**, but the present invention is not limited thereto. The metal layer **31** and the first metal layer **21** may have the same thickness.

In the second step, as shown in FIGS. **2**A and **3**A, the first metal layer **21** is partially removed in the strip shape by etching to expose a strip-shaped portion **21***a*. More concretely, a resist film is formed on the first metal layer **21** except for the exposed strip-shaped portion **21***a* in which the first metal layer **21** is removed, and a portion of the first metal layer **21** with no resist film is dissolved by etching.

In the third step, as shown in FIG. **2**C, the laser beam L is irradiated obliquely to the first main plane **10***a* including the exposed strip-shaped portion **21***a* from which the first metal layer **21** is removed. As this laser beam, more specifically, e.g. excimer laser, UV (ultraviolet) laser can be used. By irradiation of the laser beam, the optical fiber receiving portion **100** and the inclined plane **101** are formed at the end of the optical fiber receiving portion **100** are formed on the substrate **10** as shown in FIGS. **2**C and **3**C. Intensity of the laser beam L is determined to the extent such that the substrate **10** can be etched by irradiation but the first metal layer **21** and the metal layer **31** cannot be etched by irradiation. Therefore, the optical fiber receiving portion **100** is formed only the part from which the first metal layer **21** is removed.

The inclined plane **101** is formed along the traveling direction of the laser beam L. In other words, when an angle of the inclined plane **101** to the first main plane **10***a* is a tilt angle θ, the inclined plane **101** having a desired shape can be formed by irradiating the laser beam L to the first main plane **10***a* at an angle corresponding to the tilt angle θ. The tilt angle θ is an obtuse angle (θ>90°), and the tilt angle θ is 135° in the present embodiment. That is, the angle made by the second main plane **10***b* and the inclined plane **101** is 45°.

The metal layer **31** on the second main plane **10***b* is not removed by irradiation of the laser beam L, and serves as a bottom of the optical fiber receiving portion **100**. This metal layer **31** supports the optical fiber **9** from the side of the second main plane **10***b* (as shown in FIG. **1**).

In the fourth step, as shown in FIG. **2**D, the second metal layer **22** is formed entirely on the inclined plane **101** formed on the substrate **10** and on the first metal layer **21** formed on the first main plane **10***a* in the third step. In the present embodiment, the second metal layer **22** is essentially consisting of copper (Cu), and formed on the first metal layer **21** and the inclined plane **101** by e.g. electroless plating. In addition, the second metal layer **22** is also formed on one surface (a surface on the side of the second main plane **10***b*) of the metal layer **31** in the optical fiber receiving portion **100**.

In the fifth step, as shown in FIG. **3**D, by partially etching the first and second metal layers **21**, **22** to form the plurality of wiring patterns **2** on the first main plane **10***a*. More specifically, a resist film is formed on the second metal layer **22** except for the regions from which the first metal layer **21** and the second metal layer **22** are removed, and the first metal layer **21** and the second metal layer **22** at the regions with no resist film is dissolved by etching from to dissolve. This resist film remains also formed on the second metal layer **22** which is formed on the inclined plane **101** and the second metal layer **22** on the inclined plane **101** remain without being removed.

In the sixth step, as shown in FIG. **2**E, nickel (Ni) plating is applied on the second metal layer **22** and the metal layer **31** on the second main plane **10***b* that remain without being removed by etching in the fifth step, to form nickel plating layers **23**, **32**. Thereafter, gold (Au) plating is further applied on the Ni layers **23** and **32** to form Au plating layers **24**, **33**. The Ni plating nickel and Au plating can be performed by e.g. electroless plating.

After performing the first to sixth steps as described above, the wiring pattern **2** consisting of a four-layer structured metal layer including the first metal layer **21**, the second metal layer **22**, the Ni plating layer **23**, and the Au plating layer **24** is formed on the first main plane **10***a* of the substrate **10**. A total thickness of the first metal layer **21** and the second metal layer **22** is e.g. 5 to 25 μm, a thickness of the Ni plating layer **23** is e.g. 15 μm or less, and a thickness of the Au plating layer **24** is e.g. 0.03 to 0.5 μm.

Further, the reflective layer **102** consisting of a three-layer structured metal layer including the second metal layer **22**, the Ni plating layer **23**, and the Au plating layer **24** is formed on the inclined plane **101**. In other words, the reflecting portion **100***a* is configured by forming the reflective layer **102** on the inclined plane **101**.

The reflective layer **102** is the metal layer which is formed by the steps of forming the wiring pattern **2** (the fourth to sixth steps). The wiring pattern **2** and the reflective layer **102** have a common layer structure except that the first metal layer **21** is formed as a lowermost layer in the wiring pattern **2**. Further, both of the wiring pattern **2** and the reflective layer **102** are plated with gold at their uppermost surfaces (the Au plating layer **24**).

On the other hand, the metal layer **3** consisting of a three-layer structured metal layer including the metal layer **31**, the Ni plating layer **32**, and the Au plating layer **33** is formed on the second main plane **10***b* of the substrate **10**. Since the second metal layers **22** provided on the wiring pattern **2** and the reflective layer **102** are formed on the metal layer **31** of the metal layer **3** in the optical fiber receiving portion **100**, the wiring pattern **2** and the metal layer **3** that are formed continuously with the reflective layer **102** are electrically connected to each other.

In the present embodiment, the wiring pattern **2** formed continuously with the reflective layer **102** is a ground pattern **2***a* which provides a ground potential (see FIG. **1**), so that the potential of the metal layer **3** is the ground potential. According to this structure, the operation of the electronic components that are mounted on the first main plane **10***a* of the substrate **10** becomes stable. Further, a ground (GND) terminal of an IC (not shown) which is mounted on the first main plane **10***a* is easily connected to the ground potential (i.e. grounded) by forming a through-hole in the substrate **10**.

FIG. **4** is a cross-sectional view showing an example of the optical module structure in the first embodiment according to the present invention. The optical module structure comprises an optical board **1** and a photoelectric conversion device **41**. The photoelectric conversion device **41** is mounted on the first main plane **10***a*, to cover the inclined plane **101** from the side of the first main plane **10***a*.

One end of the optical fiber **9** is accommodated (received) in the optical fiber receiving portion **100** and an end face **9***a* thereof is facing the reflective layer **102**. The optical fiber **9** has a tubular cladding layer **91** on an outer periphery of the core **90**. In FIG. **4**, a light path (optical path) LP of a light propagating through the optical fiber **9** as a transmission medium is indicated by a dashed line.

When the light is output from the optical fiber **9** (core **90**), the reflective layer **102** reflects an output light toward the first main plane **10***a*. In the case that the photoelectric conversion device **41** is a light receiving element, the light reflected by the reflective layer **102** is input to the photoelectric conversion device **41** through a light emitting/receiving portion **410***a* provided on a main body **410** of the photoelectric conversion device **41**, and the photoelectric conversion device **41** converts an optical signal of this input light into an electrical signal.

In the case that the photoelectric conversion device **41** is a light emitting element, the photoelectric conversion device **41** converts an electric signal supplied from the semiconductor circuit device **41** into an optical signal, and the light representing this optical signal is output from the light emitting/receiving portion **410***a*. The output light is reflected at the reflective layer **102** and input to the core **90** of the optical fiber **9** through which the output light propagates.

Functions and Effects of the First Embodiment

According to the present embodiment, the following effects and advantages can be obtained.

(1) The optical fiber receiving portion **100** is formed to penetrate through the substrate **10** in the thickness direction of the substrate **10**, so that the optical fiber receiving portion **100** and the inclined plane **101** can be formed by irradiating the laser beam. Thus, the optical fiber receiving portion **100** and the inclined plane **101** can be formed at the substrate **10** without using e.g. a mold.

(2) The optical fiber receiving portion **100** is formed to penetrate through the substrate **10** in the thickness direction of the substrate **10**, so that the optical board **1** can be formed thinner than e.g. an optical board comprising a groove-like receiving part for receiving an optical fiber. In other words, the thickness of the optical board **1** can be substantially equal to a diameter of the optical fiber **9** (e.g. the thickness of the optical board **1** is within 20%±of the diameter of the optical fiber **9**).

(3) The reflective layer **102** is electrically conductive and formed continuously with the wiring pattern **2**, so that the wiring pattern **2** and the metal layer **3** can be connected electrically to each other without providing the substrate **10** with e.g. a through-hole.

(4) The inclined plane **101** of the substrate **10** is formed by the irradiation of the laser beam, so that it is possible to form its surface as a flat surface with high accuracy. This allows the light output from the photoelectric conversion device **41** to reflect toward the optical fiber **9** accurately, or the light output from the optical fiber **9** to reflect toward the photoelectric conversion device **41** accurately.

(5) Each of the wiring pattern **2** and the reflective layer **102** is plated with Au plating at the uppermost layer thereof, so that it is possible to suppress a decrease in reflectance of the reflective layer **102** due to corrosion, and to provide an excellent electrical connection between the wiring pattern **2** and the photoelectric conversion device **41**.

(6) Each layer in the reflective layer **102** is formed on the inclined plane **101** of the substrate **10** during the process for forming the wiring pattern **2**. That is, since there is no need for a special step for forming the reflective layer **102**, the manufacturing time of the optical board **1** and the manufacturing cost can be reduced.

(Modification)

For example, the optical board **1** according to the first embodiment can be modified as follows.

FIG. **5** is a cross-sectional view taken along line A-A of FIG. **4** showing an example of an optical module structure in a modification of the first embodiment. FIG. **5** shows the state that the optical fiber **9** is fixed in the optical fiber receiving portion **100**.

The optical module structure in the present modification has a common structure to the optical module according to the first embodiment, except the means for fixing the optical fiber **9**. Therefore, same reference numerals are assigned to the parts having the same function and the description thereof is omitted.

In this modification, the optical fiber **9** is fixed in the optical fiber receiving portion **100** by solder **5** without using the retainer member **8**. More specifically, the solder **5** is adhered to the uppermost surface of the metal layer formed at portions sandwiching the optical fiber receiving portion **100** in the first main plane **10***a* of the substrate **10** and at an inner surface of the optical fiber receiving portion **100** (specifically, the Au plating layer **24**), so that the optical fiber **9** is fixed in the optical fiber receiving portion **100**. It is sufficient that the solder **5** is adhered at least to the Au plating layer **24** formed at the portions sandwiching the optical fiber receiving portion **100** in the first main plane **10***a* of the substrate **10** and that an opening of the optical fiber receiving portion **100**, which is opened toward the first main plane **10***a* is sealed.

For this modification, it is not necessary to provide a separate retainer member **8**, and it is possible to fix the optical fiber **9** in the step of fabricating the optical board **1**.

Second Embodiment

Next, a second embodiment of the present invention will be described with reference to FIGS. **6** to **8**. The method for fabricating the optical board **1** in the second embodiment is different in the second and third steps from those in the method for fabricating the optical board **1** in the first embodiment. In FIGS. **6** to **8**, the same reference numerals are assigned to the parts having the same function as to the description of the optical board **1** and the description thereof is omitted.

In the present embodiment, a first metal layer **21**A is formed instead of the first metal layer **21** in the first embodiment, a second metal layer **22**A is formed instead of the second metal layer **22**, Ni plating layer **23**A is formed instead of the Ni plating layer **23**, and Au plating layer **24**A is formed instead of the Au plating layer **24**. Materials of respective metal layers and respective plating layers are common to those in the first and the second embodiments. The first metal layer **21**A, the second metal layer **22**A, the Ni plating layer **23**A, and the Au plating layer **24**A constitute a wiring pattern **2**A in the present embodiment. The second metal layer **22**A covers the first metal layer **21**A, and the second metal layer **22**A is partially formed on the first main plane **10***a*. In addition, the second metal layer **22**A is formed continuously from a region on the inclined plane **101** toward a region on the first metal layer **21**A, to form the reflective plane **102**. The Ni plating layer **23**A and the Au plating layer **24**A are formed on the second metal layer **22**A.

FIGS. **6**A to **6**E are cross-sectional views showing the process for forming a reflecting portion **100***a* and a peripheral portion thereof the optical board **1** in the second embodiment.

FIGS. 7A and 7B are plan views showing the process for forming the reflecting portion **100**a and the peripheral portion thereof viewed from the side of the first main plane **10**a of the optical board **1** in the second embodiment, and FIG. 7C is a cross-sectional view taken along line B-B of FIG. **7**B.

In the second step in the present embodiment, a length L_0 (in a longitudinal direction) of a strip-shaped exposed portion **21**Aa, which is exposed by partially removing the first metal layer **21**A by etching, is longer than a length in a longitudinal direction of the strip-shaped portion **21**a in the first embodiment. More specifically, an area of the resist film formed on the first metal layer **21**A is formed to be smaller than an area of the resist film in the first embodiment, to dissolve the first metal layer **21**A over a wider area than that in the first embodiment.

In the third step, similarly to the first embodiment, the inclined plane **101** is formed by irradiating the laser beam L obliquely to the first main plane **10**a. At this time, a region to be irradiated by the laser beam L in the first main plane **10**a is shifted toward an end face **10**c of the substrate **10** from a position distant for a predetermined length L_1 along the longitudinal direction of the strip-shaped exposed portion **21**Aa from an end face **21**Ab of the first metal layer **21**A, which is facing the strip-shaped exposed portion **21**Aa. In other words, an end portion **101**A of the inclined plane **101** facing to the first main plane **10**a is located at a region which is distant for the predetermined length L_1 along the longitudinal direction of the optical fiber receiving portion **100** from the end face **21**Ab of the first metal layer **21**A at the first main plane **10**a. Thus, the light with the intensity which can etch the substrate **10** will not be irradiated to a region, a distance of which from the end face **21**Ab is less than the predetermined distance L_1.

The predetermined distance L_1 is set to be such a dimension that a level difference between the surface **21**Ac of the first metal layer **21**A and the first main plane **10**a of the substrate **10** at the end face **21**Ab does not affect the flatness of the surface **22**Aa of the second metal layer **22**A which is formed at the inclined plane **101**. In other words, the predetermined distance L_1 has such a dimension that any protrusion **210** (see FIG. **4**) is not formed at the reflective layer **102**. The protrusion **210** is a bulged portion of the reflective layer **102** formed near the end portion **101**A facing the first main plane **10**a of the inclined plane **101** and is generated by raising of the second metal layer **22** which is formed continuously from the portion on the first metal layer **21** to the portion on the inclined plane **101** due to the level difference between the surface of the first metal layer **21** and the first main plane **10**a in the vicinity of the end portion of the inclined plane **101**. This predetermined distance L_1 is, for example, longer than a thickness of the wiring pattern **2**A in a stacking direction.

The length L_0 of the strip-shaped exposed portion **21**Aa in the longitudinal direction is a total of the predetermined distance L**1**, the length L_2 of the inclined plane **101** along the longitudinal direction of the strip-shaped exposed portion **21**Aa, and a length L_3 of the optical fiber receiving portion **100** in the longitudinal direction ($L_0=L_1+L_2+L_3$).

FIG. **8** is a cross-sectional view showing an example of an optical module structure in the second embodiment.

In the present embodiment, since the end face **21**Ab of the first metal layer **21**A is spaced from the end portion **101**A of the inclined plane **101** for the predetermined distance L_1, the reflective layer **102**A constituted from the second metal layer **22**A, the Ni plating layer **23**A and the Au plating layer **24**A is formed to be flat entirely over the reflecting portion **100**a. Therefore, as shown in FIG. **8**, the light output from the core **90** of the optical fiber **9** or the light output from the light emitting/receiving portion **410**a is reflected accurately even at a portion close to the first main plane **10**a in the reflecting portion **100**a, and is input to the photoelectric conversion device **41** or the core **90** of the optical fiber **9**

Functions and Effects of the Second Embodiment

In the second embodiment described above, following functions and effects can be achieved in addition to the functions and effects (1) to (6) of the first embodiment.

In the third step, the inclined plane **101** is formed by irradiating the laser beam L to the region which is shifted toward the end face **10**c of the substrate **10** from the position distant for the predetermined length L_1 along the longitudinal direction of the strip-shaped exposed portion **21**Aa from the end face **21**Ab of the first metal layer **21**A, which is facing the strip-shaped exposed portion **21**Aa. In other words, an end portion of the inclined plane **101**, which is facing to the first main plane **10**a is located at a region which is distant for the predetermined length L_1 along the longitudinal direction of the optical fiber receiving portion **100** from the end face **21**Ab of the first metal layer **21**A at the first main plane **10**a. Therefore, the protrusion **210**, which may be formed in the case that the end face **21**Ab is close to the inclined plane **101**, is not formed on the reflective layer **102**A. In other words, by locating the end face **21**Ab distantly from the region to be irradiated with the laser beam L, it is possible to prevent the level difference between the surface **21**Ac of the first metal layer **21**A and the first main plane **10**a of the substrate **10** from affecting on the shape of the second metal layer **22**A on the inclined plane **101**. Thus, it is possible to reflect the light accurately at the entire surface of the reflecting portion **100**a. Therefore, it is possible to input more light output from the core **90** of the optical fiber **9** or the light emitting/receiving portion **410**a to the photoelectric conversion device **41** or the core **90** of the optical fiber **9** certainly.

Summary of the Embodiments

Next, the technical concept that is understood from the above-described embodiments will be described with referring to the reference numerals in the embodiments. However, the respective reference numerals in the following description will not limit elements in claims of the present invention to the concrete parts shown in the embodiments.

(i) An optical board (**1**) comprising a substrate (**19**) including a plate-shaped resin including a first main plane (**10**a) and a second main plane (**10**b) facing each other, and a slit-shaped optical fiber receiving portion (**100**) which penetrates between the first main plane (**10**a) and the second main plane (**10**b) in a thickness direction, a metal layer (**31**) provided on the second main plane (**10**b), and a wiring pattern (**2**,**2** A) consisting of metal and provided on the first main plane (**10**a), in which an inclined plane (**101**) is provided at an end of the optical fiber receiving portion (**100**) in the substrate (**10**), a tilt angle (θ) of the inclined plane (**101**) with respect to the first main plane (**10**a) is an obtuse angle, and a reflective layer (**102**, **102**A) is provided on the inclined plane (**101**) for reflecting a light output from an optical fiber (**9**) received in the optical fiber receiving portion (**100**) toward the first main plane (**10**a).

(ii) The optical board according to (i), in which the wiring pattern (**2**, **2**A) and the metal layer (**31**) provided on the second main plane (**10**b) are electrically connected to each other by the reflective layer (**102**, **102**A) on the inclined plane (**101**).

(iii) The optical board (**1**) according to (i) or (ii), in which the optical fiber receiving portion (**100**) and the inclined plane

(**101**) are formed by irradiating the laser beam (L) to the first main plane (**10***a*) at an angle corresponding to the tilt angle (θ).

(iv) The optical board (**1**) according to any one of (i) to (iii), in which the reflective layer (**102**, **102**A) and the wiring pattern (**2**, **2**A) are plated with gold (Au) plating at their outermost surface.

(v) The optical board (**1**) according to any one of (i) to (iv), in which the wiring pattern (**2**A) includes a first metal layer (**21**A) and a second metal layer (**22**A) covering the first metal layer (**21**A), and the inclined plane (**101**) includes an end portion (**101**A) facing an end portion of the first the main plane (**10***a*), which is located at a position distant from an end face (**21**Ab) of the first metal layer (**21**A) of the first main plane (**10***a*) for a predetermined distance (L_1) along a longitudinal direction of the optical fiber receiving portion (**100**).

(vi) The optical board (**1**) according to (v), in which the second metal layer (**22**A) is provided continuously from a position above the first metal layer (**21**A) to the inclined plane (**101**) to form the reflective layer (**102**).

(vii) The optical board (**1**) according to (v) or (vi), in which the predetermined distance (L_1) is set to be such a dimension that a level difference between a surface (**21**Ac) of the first metal layer (**21**A) and the first main plane (**10***a*) of the substrate (**10**) at an end face (**21**Ab) does not affect a flatness of a surface (**22**Aa) of the second metal layer (**22**A) which corresponds to the inclined plane (**101**).

(viii) The optical board (**1**) according to (v), in which the optical fiber (**9**) is fixed in the optical fiber receiving portion (**100**) by a solder (**5**).

(ix) A method for manufacturing an optical board (**1**) comprising a first step of forming a first metal layer (**21**, **21**A) on a first main plane (**10***a*) of a substrate (**10**) comprising a plate-shaped resin as well as forming a metal layer (**31**) on a second main plane (**10***b*), a second step of partially removing the first metal layer (**21**, **21**A) to expose a strip-shaped portion (**21**Aa), and a third step of irradiating laser beam (L) obliquely to the exposed strip-shaped portion (**21**Aa), to form an optical fiber receiving portion (**100**) and an inclined plane (**101**) at an end of the optical fiber receiving portion (**100**).

(x) The method for manufacturing an optical board (**1**) according to (ix), further comprising a fourth step of forming a second metal layer (**22**, **22**A) on the inclined plane (**101**) and the first metal layer (**21**, **21**A) of the first main plane (**10***a*), and a fifth step of partially etching the first metal layer (**21**, **21**A) and the second metal layer (**22**, **22**A) to form a wiring pattern (**2**, **2**A) on the first main plane (**10***a*).

(xi) The method for manufacturing an optical board (**1**) according to (ix) or (x), in which a region to be irradiated by the laser beam (L) in the third step is distant from an end face (**21**Ab) of the first metal layer (**21**A) facing the strip-shaped exposed portion (**21**Aa) for a predetermined distance (L_1) along a longitudinal direction of the strip-shaped exposed portion (**21**Aa).

(xii) The method for manufacturing an optical board (**1**) according to (xi), in which the predetermined distance (L_1) is set to be such a dimension that a level difference between a surface (**21**Ac) of the first metal layer (**21**A) and the first main plane (**10***a*) of the substrate (**10**) at an end face (**21**Ab) does not affect a flatness of a surface (**22**Aa) of the second metal layer (**22**A) which corresponds to the inclined plane (**101**).

(xiii) The method for manufacturing an optical board (**1**) according to any one of (ix) to (xii), in which the third step comprises irradiating a laser beam (L) obliquely to the first main plane (**10***a*) at an angle corresponding to a tilt angle (θ) of the inclined plane (**101**) to the first main plane (**10***a*).

(xiv) The method for manufacturing an optical board (**1**) according to any one of (ix) to (xii), in which the third step comprises irradiating a laser beam (L) perpendicularly to the first main plane (**10***a*) with the use of a shadow mask with a controlled laser beam transmittance.

(xv) The method for manufacturing an optical board (**1**) according to any one of (ix) to (xii), in which the inclined plane (**101**) is formed by machining.

(xvi) An optical module structure, comprising the optical board according to any one of (i) to (viii) and a photoelectric conversion device (**41**) for converting an optical signal to be transmitted through an optical fiber (**100**) into an electric signal or an electric signal into the optical signal, in which the photoelectric conversion device (**41**) is mounted on the first main plane (**10***a*), to cover the inclined plane (**101**).

Although the embodiments of the present invention have been described, the embodiments described above are not intended to limit the invention according to the claims. In addition, it should be noted that all the combinations of the features described in the embodiment of the present invention are not necessarily essential for the means for solving the problems.

Further, the present invention can be embodied with appropriate modification without departing from the scope thereof. For example, the description in the above embodiments has been given for the case that the metal layer **3** is a so-called solid pattern provided on an entire surface of the second main plane **10***b*. However, the metal layer **3** may be partially etched to provide a wiring pattern in a desired shape. In this case, electronic components may be also mounted on the second main plane **10***b*.

Further, in the embodiments described above, the case of forming a single optical fiber receiving portion **100** and a single optical module structure in the optical board **1** has been described. The present invention is however not limited thereto. A plurality of optical fiber receiving portions **100** and a plurality of optical boards **1** may be formed in the optical board **1**.

Further, in the embodiments described above, the case where the first metal layers **21**, **21**A, the second metal layers **22**, **22**A, and the metal layer **31** are made of copper (Cu) has been described. The present invention is however not limited thereto. All or part of the first metal layers **21**, **21**A, the second metal layers **22**, **22**A and the metal layer **31** may be made of e.g. aluminum (Al). The materials of each layer of the wiring pattern **2**, **2**A and the metal layer **3** are not limited to the materials described above. Also, the material of the substrate **10** is not limited to polyimide. For example, PET (Polyethylene terephthalate) may be used as the material of the substrate **10**.

Still further, in the embodiments described above, the inclined plane **101** is formed by irradiating the laser beam L obliquely to the first main plane **10***a*. The preset invention is not limited thereto. The inclined plane **101** may be formed by irradiating the laser beam L perpendicularly to the first main plane **10***a* with the use of a shadow mask with a controlled laser beam transmittance which is adjusted in response to a depth (perpendicular distance) from the first main plane **10***a*. In the case of using the shadow mask, it is not necessary to irradiate the laser beam obliquely to first main plane **10***a*, so that the formation of the inclined plane **101** becomes easier.

Further, in the embodiments described above, the inclined plane **101** is formed by irradiating the laser beam L obliquely to the first main plane **10***a*. The present invention is not limited thereto. The inclined plane **101** may be formed by machining such as dicing. In the case of using the machining, the inclined plane **101** may be formed at a lower cost than the processing by the laser beam.

What is claimed is:

1. An optical board comprising:

a substrate including a plate-shaped resin including a first main plane and a second main plane facing each other, and a slit-shaped optical fiber receiving portion which penetrates completely between the first main plane and the second main plane in a thickness direction;

a metal layer provided on the second main plane; and a wiring pattern consisting of metal and provided on the first main plane, wherein an inclined plane is provided at an end of the optical fiber receiving portion in the substrate, a tilt angle of the inclined plane with respect to the first main plane is an obtuse angle, and

a reflective layer is provided on the inclined plane for reflecting a light output from an optical fiber received in the optical fiber receiving portion toward the first main plane,

wherein an optical fiber is sandwiched between two planes penetrating completely through the substrate.

2. The optical board according to claim **1**, wherein the wiring pattern and the metal layer provided on the second main plane are electrically connected to each other by the reflective layer on the inclined plane.

3. The optical board according to claim **1**, wherein the optical fiber receiving portion and the inclined plane are formed by irradiating the laser beam to the first main plane at an angle corresponding to the tilt angle.

4. The optical board according to claim **1**, wherein the reflective layer and the wiring pattern are plated with gold (Au) plating at their outermost surface.

5. The optical board according to claim **1**, wherein the wiring pattern includes a first metal layer and a second metal layer covering the first metal layer, and the inclined plane includes an end portion facing the first main plane end portion, which is located at a position distant from an end face of the first metal layer of the first main plane for a predetermined distance along a longitudinal direction of the optical fiber receiving portion.

6. The optical board according to claim **5**, wherein the second metal layer is provided continuously from a position above the first metal layer to the inclined plane to form the reflective layer.

7. The optical board according to claim **5**, wherein the predetermined distance is set to be such a dimension that a level difference between a surface of the first metal layer and the first main plane of the substrate at an end face does not affect a flatness of a surface of the second metal layer which corresponds to the inclined plane.

8. The optical board according to claim **5**, wherein the optical fiber is fixed in the optical fiber receiving portion by a solder.

9. A method for manufacturing an optical board comprising:

a first step of forming a first metal layer on a first main plane of a substrate comprising a plate-shaped resin as well as forming a metal layer on a second main plane;

a second step of partially removing the first metal layer to expose a strip-shaped portion; and

a third step of irradiating laser beam obliquely to the exposed strip-shaped portion, to form an optical fiber receiving portion that penetrates completely through the substrate in a thickness direction, and an inclined plane at an end of the optical fiber receiving portion.

10. The method for manufacturing an optical board according to claim **9**, further comprising:

a fourth step of forming a second metal layer on the inclined plane and the first metal layer of the first main plane;

a fifth step of partially etching the first metal layer and the second metal layer to form a wiring pattern on the first main plane, and

a sixth step of electrically connecting the wiring pattern to the metal layer on the second main plane.

11. The method for manufacturing an optical board according to claim **9**, wherein a region to be irradiated by the laser beam in the third step is distant from an end face of the first metal layer facing the exposed strip-shaped portion for a predetermined distance along a longitudinal direction of the exposed strip-shaped portion.

12. The method for manufacturing an optical board according to claim **11**, wherein the predetermined distance is set to be such a dimension that a level difference between a surface of the first metal layer and the first main plane of the substrate at an end face does not affect a flatness of a surface of the second metal layer which corresponds to the inclined plane.

13. The method for manufacturing an optical board according to claim **9**, wherein the third step comprises irradiating a laser beam obliquely to the first main plane at an angle corresponding to a tilt angle of the inclined plane to the first main plane.

14. The method for manufacturing an optical board according to claim **9**, wherein the third step comprises irradiating a laser beam perpendicularly to the first main plane with the use of a shadow mask with a controlled laser beam transmittance.

15. The method for manufacturing an optical board according to claim **9**, wherein the inclined plane is formed by machining.

16. An optical module structure, comprising:

an optical board comprising: a substrate including a plate-shaped resin including a first main plane and a second main plane facing each other, and a slit-shaped optical fiber receiving portion which penetrates completely between the first main plane and the second main plane in a thickness direction; a metal layer provided on the second main plane; and

a wiring pattern consisting of metal and provided on the first main plane; and a photoelectric conversion device for converting an optical signal to be transmitted through an optical fiber into an electric signal or an electric signal into the optical signal,

wherein an inclined plane is provided at an end of the optical fiber receiving portion in the substrate, a tilt angle of the inclined plane with respect to the first main plane is an obtuse angle, and a reflective layer is provided on the inclined plane for reflecting a light output from an optical fiber received in the optical fiber receiving portion toward the first main plane, wherein the photoelectric conversion device is mounted on the first main plane, to cover the inclined plane, and

wherein an optical fiber is sandwiched between two planes penetrating completely through the substrate.

17. The optical board according to claim **1**, wherein the metal layer on the second main plane forms the bottom of the optical fiber receiving portion.

18. The optical board according to claim **9**, wherein the metal layer on the second main plane forms the bottom of the optical fiber receiving portion.

19. The optical board according to claim **9**, wherein an optical fiber is sandwiched between two planes penetrating completely through the substrate.

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